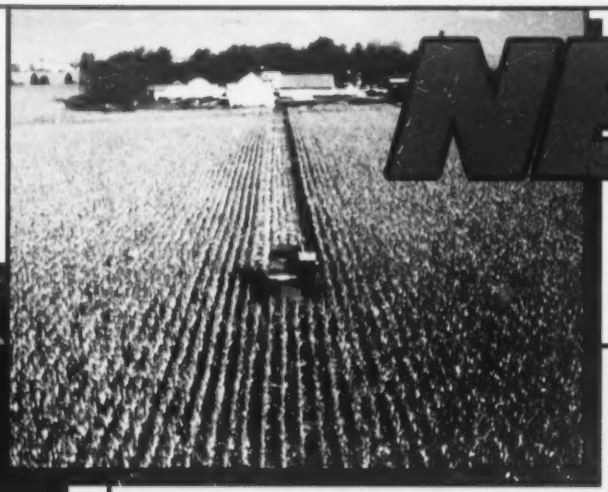
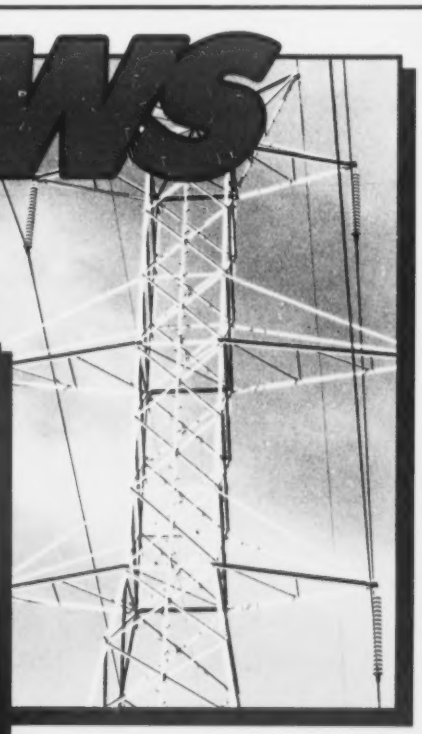
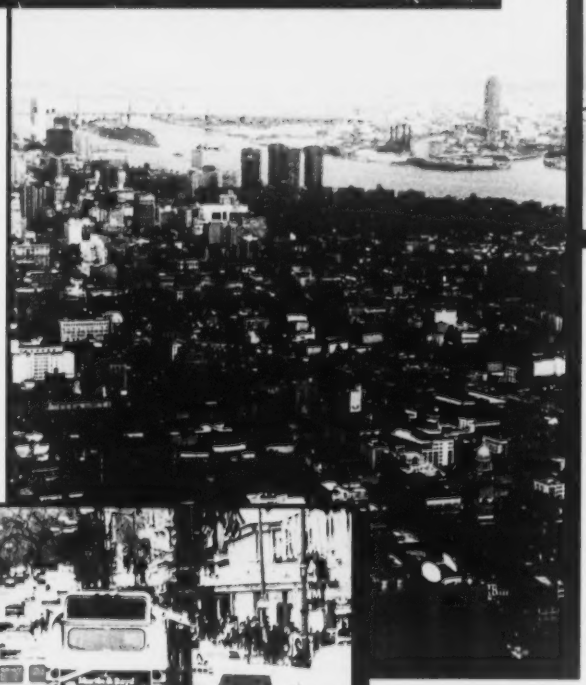
APRIL 1, 1991

CHEMICAL & ENGINEERING

NEWS







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Greenhouse Gases

Weighing the costs of controlling emissions *Page 7*

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News of the Week

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LETTERS

Sharing credit

The announcement of the Wolf Prize in Chemistry (C&EN, Jan. 14, page 22) attributes cross-polarization magic-angle spinning to Alexander Pines working with John Waugh. In fact, it is well known that Jacob Schaefer, Samuel Weissman, and Edward Stejskal were the first to employ magic-angle spinning for carbon-13 in solids. The historical context of cross-polarization nuclear magnetic resonance has been discussed on many occasions, most recently in "Current Contents" (Proton-enhanced NMR of dilute spins in solids, Citation Classics, in press).

A. Pines
Berkeley, Calif.

Risk assessment of pesticides

The News Forum, "Risk Assessment of Pesticides" (C&EN, Jan. 7, page 27) contains a rebuttal by Joseph K. Haseman and James E. Huff that is headlined, "Arguments that discredit animal studies lack scientific support." That oversimplified headline and its amplification in the text should not go unanswered. The detailed answers are contained in the proceedings of three symposia and a book of invited presentations:

- A January 1986 Food & Drug Administration-sponsored symposium (conducted by the Federation of American Societies for Experimental Biology) on "Biological Bases for Interspecies Extrapolation of Carcinogenic Data." Copies of the proceedings are available from FASEB, 9650 Rockville Pike, Bethesda, Md. 20814.
- "Proceedings: New Directions in the Extrapolation of Health Risks from Animals to Man." Vol. I, "Extrapolation from Animals to Man." Vol. II, "Toxicokinetics." Electric Power Institute (1986). Request copies from Research Reports Center, P.O. Box 50490, Palo Alto, Calif. 94303.
- "Human Risk Assessment: the Role of Animal Selection and Extrapolation," M. V. Roloff, Editor, Taylor & Francis, London (1987).
- "Proceedings of the Pharmacokinetics in Risk Assessment Workshop" (Oct. 1986). "Drinking Water and Health." Vol. 8, "Pharmacokinetics." National Academy Press, Washington, D.C. (1988).

In addition, several professional advisory groups have expressed reservations concerning the validity of relating results of chronic studies with animals to effects on humans exposed to the chemical studied. The American Medical Association's Council on Scientific Affairs expressed concern [*J. Am. Med. Assoc.* **246**, 253 (1981)] "about the hundreds of millions of dollars that are spent each year ... for carcinogenicity testing of chemical substances ... in view of the questionable scientific value of the tests when used to predict human experience."

An interagency staff group in a review document [*Fed. Reg.*, **49**, 21594 (1984)] prepared for the President's Office of Science & Technology Policy noted that "while there is a significant amount of evidence to support qualitative animal to human extrapolation for carcinogenesis, the evidence falls short of establishing this proposition as a scientific fact. ... This principle [that an animal carcinogen should be considered a suspect human carcinogen] has been accepted by all health and regulatory agencies and is regarded widely by scientists in industry and academia as a justifiable and necessary interference." An Interdisciplinary Panel on Chemical Carcinogenicity, convened at the request of the American Industrial Health Council, advised [*Science*, **225**, 682 (1984)] that "data derived from animal studies, although suggestive of carcinogenic risk, may require additional study before extrapolation to conditions of human exposure can be made. Interpretation of ... different patterns of tumor development in test animals should recognize the likelihood that these represent different mechanisms and may have different significance to human risk."

And finally, a Subpanel on Design of Chronic Studies in a 1984 report of the National Toxicology Program Ad Hoc Panel on Chemical Carcinogenesis Testing and Evaluation "stressed that ... extrapolation from species to species and from rodents to man are generally carried out for public health purposes; they do not necessarily imply extrapolation on a scientific basis in all respects for each species. Such estimates are often required to meet societal needs, and are subject to change when further scientific information becomes available."

In brief, the argument is not against studies with animals, but in the way they are interpreted. The argument is against the simplistic counting of lesions. As stated by a pioneer toxicologist-biochemist, Bernard Oser [*J. Toxicol. Environ. Health*, **8**, 521 (1981)], "We should take into account the differences between humans and rats when we plan and interpret studies in rats, and not fall into the trap of replacing good judgment

Greenhouse gas controls could hit chemical industry hard

The U.S. chemical industry—which relies on fossil fuels not only for fuel and power, but also for raw materials—is one of the most energy-intensive manufacturing groups. According to the Chemical Manufacturers Association (CMA), the U.S. industry's 1989 energy consumption of about 5.3 quadrillion Btu was about 7% of the U.S. total.

The chemical industry is the single largest user of natural gas in the nation, consuming about 10% of the total, CMA says. And it uses about 6% of all petroleum products consumed in the U.S.

So if the U.S. chooses a strategy of limiting greenhouse gas emissions through increased energy prices, the impact of higher energy costs could hit the chemical industry hard. It uses relatively little coal, the energy source that will increase most in price if a carbon tax is instituted. But competition from other energy consumers switching away from coal will force up the prices of oil and gas.

However, several factors unique to the industry could ease the pain, says Marc H. Ross, professor of physics at the University of Michigan, Ann Arbor. Ross, who analyzes both the technical and policy aspects of industrial energy use, is currently on sabbatical at Lawrence Berkeley Laboratory.

"The chemical industry may be in a better position than most," Ross says. "There is so much technical capability within the industry. Chemical engineers are trained to study the flow of energy and materials. The industry has been one of the most successful in reducing energy intensity in the past."

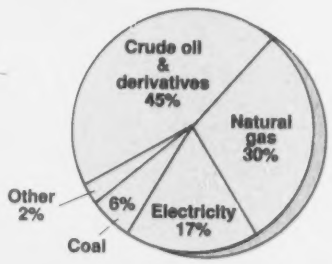
The industry's well-established pattern of growth will help, Ross adds, pointing out that new plants are more energy-efficient than old ones. So will continuing process improvements: New developments in catalysis, sensors, and control systems all should contribute to decreased energy demand.

And most industrial chemistry processes are still very far from thermodynamic limits in efficiency, he says, if one compares the ratio of energy used to the minimum required. "In cases where heat is required we use much more energy than theoretically necessary. And in principle we could extract energy from energy-releasing reactions."

The ongoing diversification of the chemical industry means that some firms would be affected by greenhouse gas controls in their roles as energy suppliers as well as energy consumers. Du Pont, for example, produces not only chemicals but also coal and oil.

"Global warming itself is a concern to Du Pont," says W. Ross Stevens III, manager of environmental affairs for the company. "And concerns over the economic impacts of controls are very real to us. We want to be sure rational choices are made. At the same time, we are aware carbon dioxide needs to be controlled."

Chemical industry relies heavily on oil and gas



Total 1989 consumption = 5.3 quads

Note: Consumption includes feedstock as well as fuel and power. Quad = quadrillion Btu.
Source: Chemical Manufacturers Association

urban poor because of heat stress and changes in the availability of water and food.

If such predictions turn out to be correct, the greatest economic damages from global warming will hit the countries that have the fewest resources to deal with them. Third World nations are already short of money for the conventional technologies needed to raise their standards of living, notes Mohan Munasinghe, the World Bank's division chief for environmental policy. Their plight is made that much worse by adding the costs of environmental damages.

Because the costs of controlling greenhouse gas emissions would be borne primarily by the industrialized world, while the benefits of avoiding the damages of global warming would be realized mostly in developing countries, the internal cost-benefit analyses of the U.S. and other developed countries may well show the costs outweigh the benefits.

That is one of the reasons Peter G. Brown, professor of public affairs at the University of Maryland, argues against addressing the issue in terms of costs and benefits. "That strategy is not appropriate to issues of planetary management," he says. Instead, Brown believes, humans have an obligation to conserve the options and quality of life available to future generations, never mind the cost.

Paul R. Portney, an economist who is vice president of Resources for the Future, a Washington-D.C.-based think tank, conceded in summing up the cost conference that cost-benefit analysis alone is inadequate to address the scope of global climate change. "We cannot now and never will satisfactorily express in dollars all the costs and benefits of control measures," he said. He noted that GNP falls short of measuring the health of an economy because it doesn't count many things people value, such as leisure and environmental quality.

"Any economist who says that a policy isn't good because GNP will go down doesn't deserve your attention," Portney went on. "Nevertheless, it's useful to think about what we will get if we pursue a specific policy and what we will have to give up.

"Is the trade-off worth it? What protections will we get if we try to stabilize climate rather than investing in a host of other problems—education, for example?"

Indeed, that is the question. Unfortunately, neither economists nor scientists yet have the answer. □

Revenues grow for some biotech companies

Ann M. Thayer,
C&EN Northeast News Bureau

In 1990, as in 1989, very few biotechnology companies broke from the ranks to become profitable. Of the 33 companies surveyed by C&EN, only six reported modest profits for the year. Revenues rose substantially for many companies but for only a few because of product sales. Although biotechnology products are beginning to reach the market, and more are expected to make it past regulatory obstacles in the next few years, the high costs of R&D and commercialization continue to take a large bite out of earnings.

Product sales for the biotechnology industry are dominated by human therapeutics and diagnostics. Agricultural companies have yet to market a major biotechnology-based product. Companies such as Ecogen, Mycogen, Calgene, and Crop Genetics—not unlike small biotechnology drug companies—continue to work on raising capital, developing products, and putting together strategic alliances to help enter the market. Sales of biopharmaceuticals reached about $1 billion in 1990, according to the San Francisco-based investment firm of Hambrecht & Quist, and could reach $2 billion by 1992.

With tissue plasminogen activator (TPA) and human growth hormone (HGH), Genentech had product sales of $367 million, a 15% growth over 1989. This was due primarily to growth in HGH sales, rather than from TPA sales, which are facing increased competition. Despite this, Genentech reported a loss of $98 million, attributed to a special charge of nearly $168 million related to its merger with Roche Holdings.

Coming into prominence in 1990 as a fully integrated biopharmaceutical company was Amgen. With its single erythropoietin (EPO) product, the company had sales of $281 million. Again, a special charge of $50 million for the acquisition of certain patent rights left Amgen with net earnings of only $3.9 million.

Revenues for Biogen, which reached $59.4 million, were largely royalty income from licensees' sales of several major products, including hepatitis B vaccine and diagnostics, and α-interferon. In 1990, the company reported its second consecutive profitable year. Chiron had its first profitable year with strong revenues from its joint blood screening and diagnostics business with Ortho Diagnostics. Other profitable companies include Applied Bioscience, an R&D services company; Immucor, a supplier of blood bank reagents and related products; and Collagen, which produces collagen-based biomedical products. Immunex, although not profitable in 1990, is in the process of launching its first product this year.

For the majority of companies, revenues come from contract or collaborative R&D. Several companies with near-term products, such as Centocor and Xoma, are expected soon to make the transition from R&D to marketing. In the meantime, they, along with Cytogen, Genetics Institute, and Cetus, reported sizable losses. This is not surprising, as these companies have been investing in product development, clinical trials, and marketing to prepare for the launch of their first drug products in the U.S.

Few biotech firms were profitable in 1990

$ Thousands	Revenues[a]	Earnings	Change from 1989 Revenues	Change from 1989 Earnings	Profit margin[b] 1990	Profit margin[b] 1989
Amgen	$300,809	$3,865	102%	3%	1%	3%
Applied Bioscience	99,650	8,149	- 27	34	8	8
Biogen	59,415	7,720	45	140	13	8
BioTechnology General	4,307	−6,217	−12	def	def	def
Calgene	32,904	−13,195	3	def	def	def
California Biotechnology	12,425	−5,131	0.5	def	def	def
Cambridge Biotech	21,854	−10,396	−6	def	def	def
Centocor	64,634	−132,180	−10	def	def	0.2
Cetus	46,765	−71,780	53	def	def	def
Chiron	78,512	6,829	121	def	9	def
Collagen	58,309	3,184	23	−12	6	8
Cytogen	4,701	−17,339	−37	def	def	def
DNA Plant Technology	13,427	−8,939	4	def	def	def
Ecogen	2,188	−7,968	−26	def	def	def
Enzo Biochem	20,962	−4,642	3	def	def	def
Genentech	476,136	−98,031	19	def	def	11
Genetics Institute	40,374	−22,873	−8	def	def	def
Genzyme	54,835	−4,542	60	def	def	def
Immucor	14,946	2,507	37	45	17	16
Immunex	34,879	−9,887	24	def	def	def
Immunogen	3,126	−7,621	297	def	def	def
Immunomedics	4,395	−2,573	60	def	def	def
Liposome	7,071	−5,005	88	def	def	def
MGI Pharma[c]	6,364	−6,429	33	def	def	46
Mycogen	14,980	−4,492	47	def	def	def
NeoRx	1,745	−16,055	−72	def	def	def
Nova Pharmaceuticals	36,095	−14,245	130	def	def	def
Oncogene Science	5,345	−3,478	20	def	def	def
Repligen	10,703	−5,702	−11	def	def	def
Ribi ImmunoChem	1,317	−2,715	6	def	def	def
Synergen	12,746	−6,412	−14	def	def	def
T Cell Sciences	12,042	−2,215	10	def	def	def
Xoma	20,476	−23,676	97	def	def	def

a. Includes product sales, contract research, royalty, and interest revenues for calendar year. b. After-tax income as percentage of sales. c. Name changed from Molecular Genetics. **def** = deficit.

Xoma and Centocor are awaiting Food & Drug Administration approval for monoclonal-antibody-based products used to treat bacterial sepsis or septic shock. With a market estimated at more than 400,000 patients, product sales are expected to do much to contribute to revenue growth and eventual profitability for either company. Centocor recently received approval in Europe. Yet to be resolved is a patent suit between the companies. In 1990, Centocor reported a loss of $132 million, having spent $115 million to reacquire rights to three products.

Another firm with a sizable loss is Cetus, which lost nearly $72 million. Cetus' much publicized problems with launching its interleukin-2 in the U.S. led to cost cutting, staff reductions, and management changes in 1990. On the positive side, Cetus' patents to polymerase chain reaction technology were recently upheld. In addition to an internal business area, PCR forms the basis of two joint ventures for the company.

Genetics Institute had major setbacks on two fronts, having been found to infringe Genentech's patents on TPA and Amgen's patent on EPO, while having its own EPO patent declared invalid. With no products on the U.S. market, Genetics Institute's short-term revenues come in part from sales of EPO overseas by licensees. Adding to this may be royalty income from Factor VII, licensed to Baxter Healthcare and pending FDA approval, from granulocyte macrophage colony-stimulating factor (GM-CSF), also awaiting approval and to be comarketed by Sandoz and Schering-Plough under license from Genetics Institute.

Just recently approved are two competing products—Amgen's G-CSF and Immunex's GM-CSF. The market for G-CSF, approved for the treatment of white blood cell deficiencies in patients undergoing cancer therapy is estimated to have as many as 250,000 patients and as much as $200 million in sales within a few years. Approvals of the CSFs mark the first in a major new class of biopharmaceuticals estimated to be worth as much as $1 billion in sales by the mid-1990s.

The CSFs—together with Genentech's γ-interferon, which was the only biopharmaceutical to be approved in 1990—are the first among what is believed will be a growing number of biotechnology drugs reaching the market in the 1990s. To date, only 14 biotechnology drugs have been approved but more than 100 products, developed by nearly 40 companies, are in clinical trials or awaiting approval.

Recent approvals of major products are focusing investor attention on promising biotechnology companies. Both Amgen's and Immunex's stock prices jumped dramatically after receiving FDA approval for their products. Patent issues also have an impact. Amgen's share price continued to rise following the outcome of the EPO patent trial, whereas Genetics Institute's share price dropped about 30%. Similarly, Cetus saw a large drop in the value of its stock when an FDA advisory committee failed to recommend approval for IL-2.

In late February and early March, biotechnology stock prices overall rose in light of renewed interest by investors. Riding this wave, several companies recently have announced public offerings of stock. In 1990, biotech stocks outperformed the stock market. According to Hambrecht & Quist, the value of biotechnology stocks as a group grew about 37%, whereas the Dow Jones Industrial Average fell just over 4%.

Although increased product sales signal growth, they also are expected to contribute to new problems facing the biotechnology industry. Reimbursement is considered a major issue of the 1990s in a survey of companies by the San Francisco-based management consulting firm Ernst & Young. "The products of biotechnology are coming into use just as the health care environment is undergoing drastic change. Government reimbursement authorities, private insurers, and corporate benefits departments all are engaged in initiatives to impose control over upwardly spiraling costs." The challenge for biotechnology companies, adds Ernst & Young, is to definitively demonstrate the value of products beyond the routine questions of safety and efficacy, providing cost-effectiveness and cost/benefit ratios, and documenting products' impact on patients' quality of life.

"There is no question about it—the drugs we are producing are truly revolutionary. They offer physicians therapeutic modalities that in some ways were never dreamed and have very attractive side effect profiles," says Harry F. Hixson Jr., until recently the president of Amgen. "But the cost of new products is not a major contributor to the overall cost of health care."

Like most biotech companies, Amgen had to raise hundreds of millions of dollars in investor capital, explains Hixson, and just now is putting a second product on the market. Thus product pricing not only takes into account existing product competition and reimbursement pressures, but also aims to recover development, marketing, and manufacturing costs, to generate capital to fund R&D for future products, and to provide shareholders with a return on their investment.

With U.S. sales expected to exceed $300 million this year, EPO pricing and reimbursement have been investigated by the Department of Health & Human Services. Pricing was approved by the Health Care Financing Organization under a program for dialysis patients. Considering the improved quality of life for dialysis patients on EPO, its cost is "not inappropriate," says Hixson. Amgen's second product, G-CSF, and additional uses for EPO will not fall under such programs. Companies also stress the ability of such drugs to decrease overall treatment time and cost.

EPO's approved use has been expanded to include the treatment of anemia in AIDS patients, a market being handled by Amgen's licensee, Ortho Biotech. The AIDS area is one already confronted with issues surrounding high-priced drugs. A program to supply EPO free of charge to those who can't afford it or to cap the cost at $8500 per year for those requiring large quantities of drug has been set up, explains Dennis Longstreet, president of Ortho Biotech. Such programs are not uncommon—Amgen has a similar program for EPO and Genentech has programs to make its products available. Hoffmann-La Roche has a program that caps costs for α-interferon, used to treat AIDS-related Kaposi's sarcoma, at $9800 per year. □

Aromatics demand to lag capacity growth

Bruce F. Greek, C&EN Houston

Overcapacity of major aromatic chemicals likely will plague producers throughout the world well into the mid-1990s, according to marketing experts meeting last month in Houston at a seminar entitled "Petrochemical Forecasts in an Uncertain World." Sponsored by consultant company Chemical Marketing Associates Inc. (CMAI), seminar participants also predicted that aromatics demand will grow at moderate rates but supply from new plants and shifts in gasoline formulations will hold down plant utilization rates despite scrappage of some production units.

Earnings from these aromatics are expected to drop this year and next, and then to recover later on. Profit margins this year for aromatics and other chemicals likely will be better than the demand-capacity relationship would indicate, because of lower prices for crude oil.

Prices of crude oil, from which some aromatics are derived, will increase on the average during 1992 and will continue to rise as worldwide economic growth boosts energy demand, says Arved Teleki, president of Hydrocarbon Consultants in Houston. Because of environmental constraints on the use of coal, nuclear power, and hydropower, the slow growth in energy conservation programs, and instability in the Middle East, oil and gas will meet much of the load of growing energy demand. Consequently, petrochemical producers will have to pass on the costs of feedstock and energy or face lowered margins.

Teleki forecasts that in 1996 the average refinery acquisition cost of crude oil will reach $36.50 per barrel in current dollars, which is higher than the all-time high of $35.24 in 1981. In constant 1990 dollars, he says, the 1996 price would translate to about $30 per bbl, compared with the 1981 price of $50 per bbl in 1990 dollars.

Among the basic aromatics, benzene demand will continue to grow following a slowdown this year. Through 1996, global demand will average 4.1% annual growth, says Mark A. Fisler of CMAI. U.S. demand alone will grow 4.3% per year, spurred by a continuing increase in the use of benzene to make ethylbenzene, he says. That use will grow an average of 5.4% annually.

In Japan, growth in benzene use, at 3% annually, will remain below the world rate, says Fisler. Growth in Japan is being stifled by the rapid increase in capacity in the Pacific Rim outside Japan. Shifting feedstocks from benzene to toluene to make cumene also causes a decline in this use of benzene.

A shift in making adipic acid directly from benzene also will cause another application of benzene, that of making cyclohexane, to fall. This decrease will be offset by a significant jump in the all-other uses category. Japan also will encounter a major overcapacity situation if all of the proposed toluene dealkylation capacity is built on schedule before 1996.

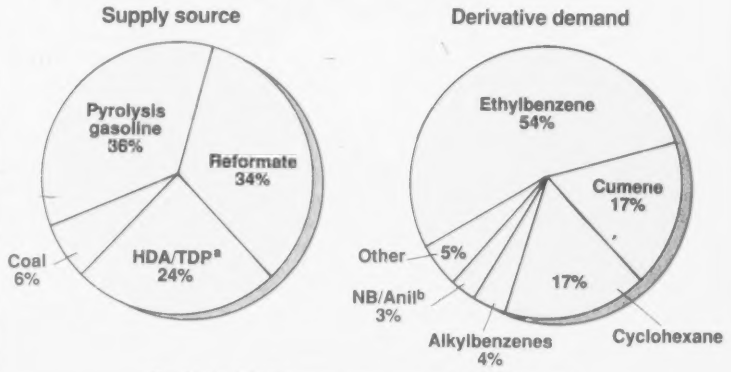
The other Pacific Rim countries, as well as Australia, China, and India, will support benzene growth of more than 13% annually through 1996. Much of the growth will be the result of increasing demand to make ethylbenzene for styrene. Meeting the demand for making derivatives could require increasing benzene imports to continue into, for example, South Korea. Behind these continuing imports are optimistic expectations of the amount of benzene to be obtained from pyrolysis gasoline as a coproduct in the making of ethylene. Low benzene production may result from any construction delays and operating problems with steam crackers in South Korea.

In Western Europe, demand for benzene will grow about 2.5% annually between 1990 and 1996. The lower rate could result partially from inclusion of East Germany's production and consumption into Western Europe totals. Another cause for lower growth stems from slowing demand for ethylbenzene, says Fisler. Shifting from benzene to *n*-butane as the feedstock for making maleic anhydride in Europe also is a contributing factor in the slower growth.

Some unusual changes in the benzene business are expected to come from implementation of the Clear Air Act amendments. For example, the use of more oxygenated compounds in gasolines may lead to a surplus of higher octane hydrocarbons, such as the aromatics, and to lower and more stable prices for these hydrocarbons.

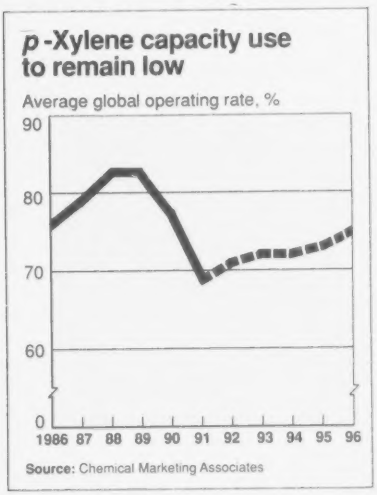
The economics of hydrodealkylation of toluene to benzene will continue to set the basic floor price for

Global benzene supply/demand for mid-1990s



Projected 1996 consumption = 8.4 billion gal

a Hydrodealkylation or disproportionation of toluene. b Nitrobenzene and aniline.
Source: Chemical Marketing Associates



benzene, but fewer and less dramatic price fluctuations will occur, according to Fisler. If catalytic reformers are operated less severely to reduce aromatics production because the demand for octane values is offset by the oxygenates, less coproduct hydrogen will be made. Therefore, pressure to find hydrogen will affect economics of both hydrodealkylation and manufacture of cyclohexane.

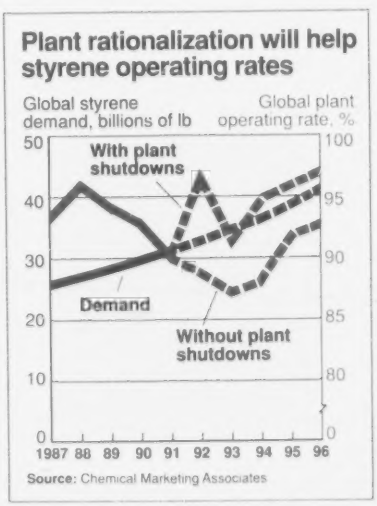
Another basic aromatic facing rapidly increasing overcapacity is *p*-xylene, Graham Copley of CMAI Europe told the seminar. Large additions to capacity are driving down average plant operating rates even as global consumption rises. In 1991, the rate will fall below 70% before beginning a slow climb up to about 77% by 1996. The operating rate in the U.S. will continue to drop from more than 93% in 1988 to under 75% in 1992, before it resumes a climb, possibly spurred by closing of some capacity in 1993.

After climbing in the second quarter of 1990 and then declining late in the year, pricing of *p*-xylene in the future will vary with several possible scenarios. The need for aromatics in gasoline influences pricing. This results in a floor on *p*-xylene prices based on the value established for the mixed xylenes stream from which *p*-xylene is extracted. Mixed xylenes are valuable because they can be blended into gasoline, Copley points out. That value may be reduced if the aromatic content of gasoline is reduced as a result of reformulation. If use of mixed xylenes is reduced, then low prices for *p*-xylene probably would make it unprofitable to recover mixed xylenes from reformate or pyrolysis gasoline. Mixed xylenes could reach a value close to that of naphtha, a feedstock for steam cracking.

Copley forecasts that contract prices for *p*-xylene then would be in the area of about break-even cash margins, or in the range of 15 to 20 cents per lb this year, rising to around 30 cents per lb in 1996. To cover capital replacement, prices would have to be 8 to 10 cents per lb more. Most U.S. and Western Europe *p*-xylene capacity now is fully depreciated, and producers will not show a loss if the mixed xylenes feedstocks cost as little as gasoline blending alternatives or less.

Need for capacity and high profitability from making styrene in the late 1980s led to a remarkable amount of new capacity being planned for the short and long term, Steve A. Knight of CMAI told the seminar. Capacity in the world, if all plans are completed, will increase from about 14.7 million metric tons in 1990 to more than 20 million metric tons in 1996. A more pressing problem is that more than 75% of the additional capacity for the monomer is planned to be operating by the end of 1993.

Some shuttering of capacity may occur because of the overcapacity.



Decisions to shut down capacity will be based on upstream and downstream integration, location, and economic factors, Knight says. For example, some 200,000 metric tons of U.S. capacity is considered almost certain to be closed because it is old, inefficient, and lacking integration.

Growth in demand for styrene will be relatively low in the U.S. For 1990 to 1996, Knight forecasts growth of 3.8% per year. But, if the years of slightly declining demand—1989 and 1990—are included, then the average growth rate between 1988 (the previous peak year at 8.1 billion lb) and 1996 will be just 2.2% per year.

Exports of styrene are forecast to help keep plant operating rates going up. The new highly competitive capacity of the U.S. will keep U.S. exports strong as demand grows in developing countries.

Global demand for styrene is forecast by Knight to exceed 41 billion lb in 1996, up from 26 billion in 1987. Growth between 1990 and 1996 will average 5.3% annually. Even if no obsolete styrene capacity is shut down, plant operating rates will increase after 1993, from a low expected of about 87%. Rationalization of styrene capacity could reverse the drop in operating rates expected next year. Then shutdowns would be more than offset by new capacity, with the rate declining in 1993, before climbing back to 97% of capacity in 1996.

Profit margins in cents per pound for styrene will not return to the almost unprofitable levels of the early 1980s. However, they will fall substantially from the range of 10 to 20 cents per lb between 1987 and 1990. Margins likely will bottom out at around 2 cents per lb next year for contract sales, Knight expects. Export or spot margins then also will return to higher levels after declining to almost nothing this year.

This lower profitability now faced by styrene makers will inhibit planning for new capacity in the 1992 to 1994 period, says Knight. Therefore, he expects to speak at a CMAI seminar in 1996 with a title something like "Styrene—Too Much Demand, Too Little Capacity." □